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Kaewell, Jr. et al.

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(45) **Date of Patent: Aug. 31, 2004**

(54) **NODE-B/BASE STATION RAKE FINGER POOLING**

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(73) Assignee: **InterDigital Technology Corporation**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/331,085**

(22) Filed: **Dec. 27, 2002**

Related U.S. Application Data

(60) Provisional application No. 60/372,531, filed on Apr. 12, 2002.

(51) **Int. Cl.**[7] **H04B 1/707**
(52) **U.S. Cl.** **375/144**
(58) **Field of Search** 375/141, 144, 375/148; 370/320, 335, 342, 441

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,237,586	A	8/1993	Bottomley	
5,329,548	A	7/1994	Borg	
5,471,509	A	11/1995	Wood et al.	
6,141,334	A	* 10/2000	Flanagan et al.	370/342
6,333,926	B1	* 12/2001	Van Heeswyk et al.	370/335
6,463,048	B1	10/2002	Garyantes	
6,618,434	B2	* 9/2003	Heidari-Bateni et al.	375/148
2002/0036998	A1	3/2002	Lomp	

FOREIGN PATENT DOCUMENTS

CN	1140365	1/1997
CN	1182986	5/1998
CN	1253424	5/2000
CN	1356802	7/2002
CN	1366390	8/2002
CN	1379932	11/2002
CN	1390001	1/2003
JP	2001-16628	1/2001
WO	01/03318	1/2001
WO	01/13530	2/2001

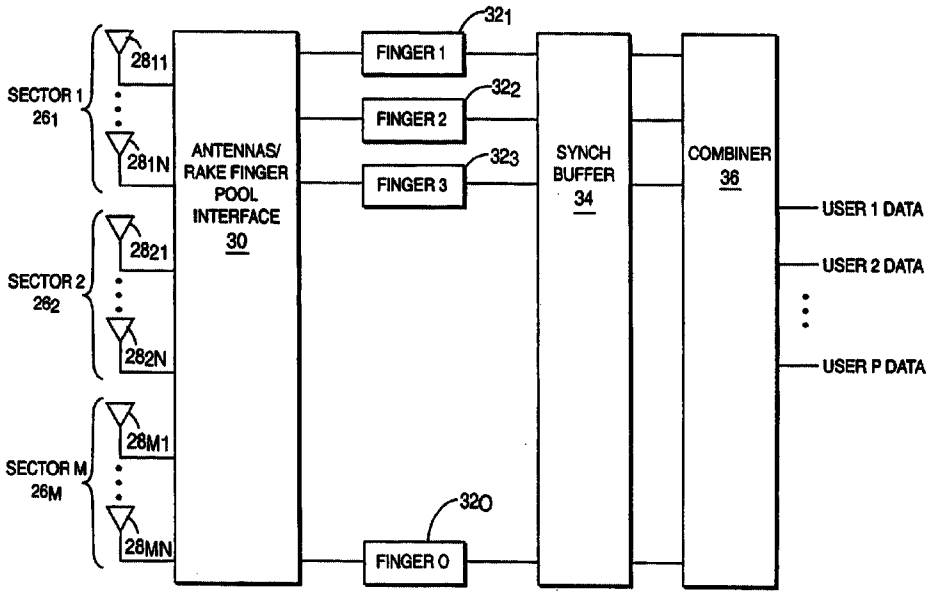
* cited by examiner

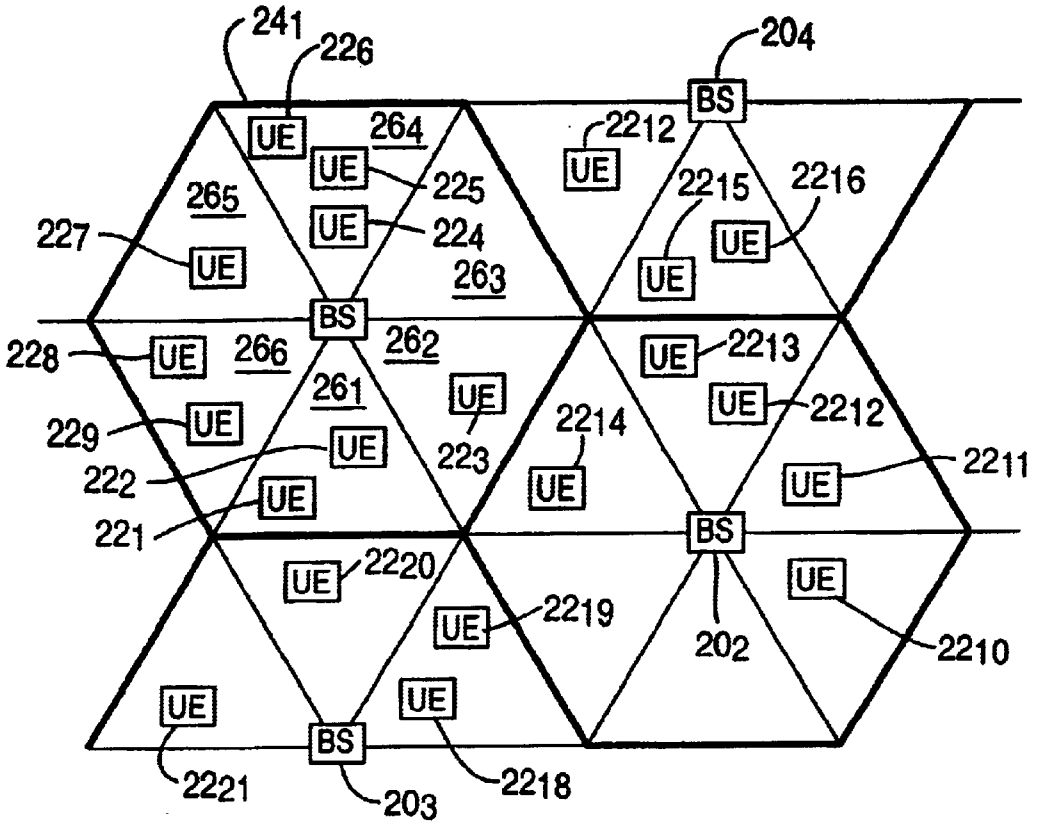
Primary Examiner—Don Vo
(74) *Attorney, Agent, or Firm*—Volpe and Koenig, P.C.

(57) **ABSTRACT**

A Node-B/base station receiver comprises at least one antenna for receiving signals. Each finger of a pool of reconfigurable Rake fingers recovers a multipath component of a user and is assigned a code of the user, a code phase of the multipath component and an antenna of the at least one antenna. An antenna/Rake finger pool interface provides each finger of the Rake pool an output of the antenna assigned to that Rake finger. A combiner combines the recovered multipath components for a user to produce data of the user.

2 Claims, 6 Drawing Sheets




241
226
204
BS
UE
264
2212
UE
225
2215
2216
265
UE
224
227
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UE
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228
UE
266
262
UE
2213
261
UE
UE
2212
229
UE
2214
UE
223
222
UE
UE
2211
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203
2218

FIG. 1

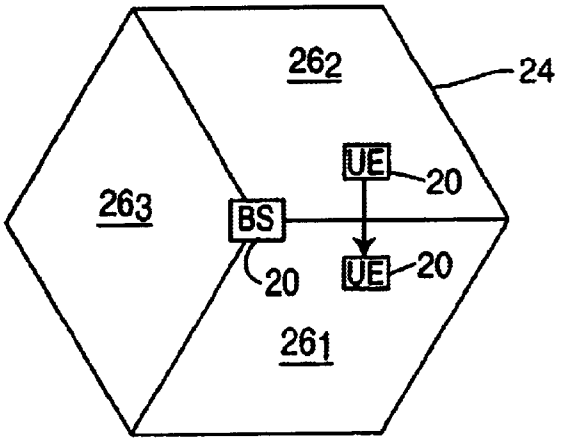

262
24
UE
20
263
BS
20
UE
20
261

FIG. 3

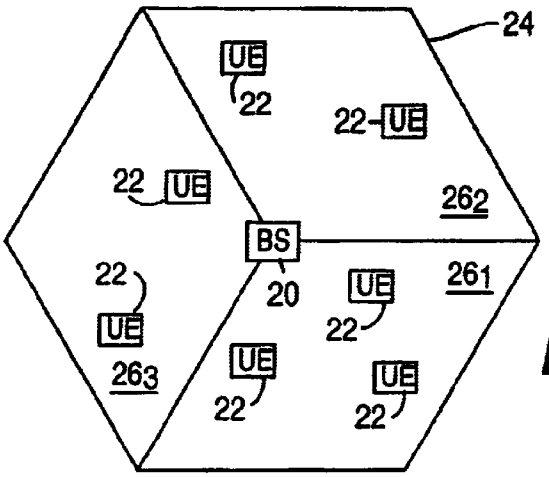


FIG. 2A

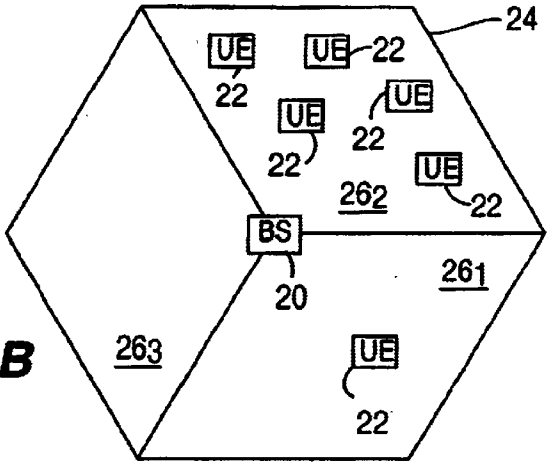


FIG. 2B

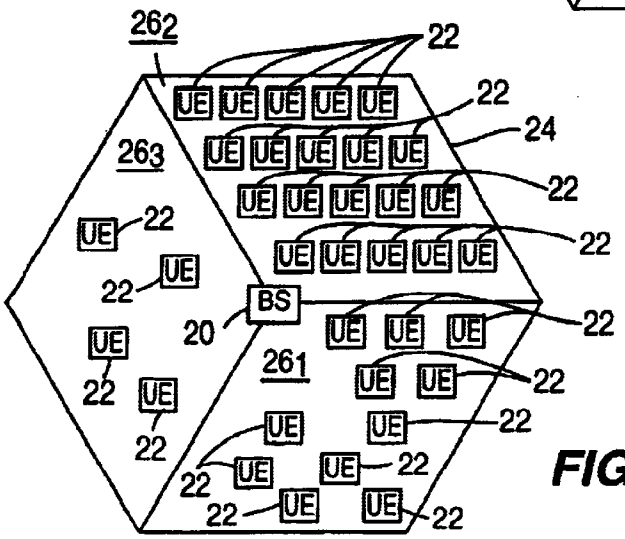
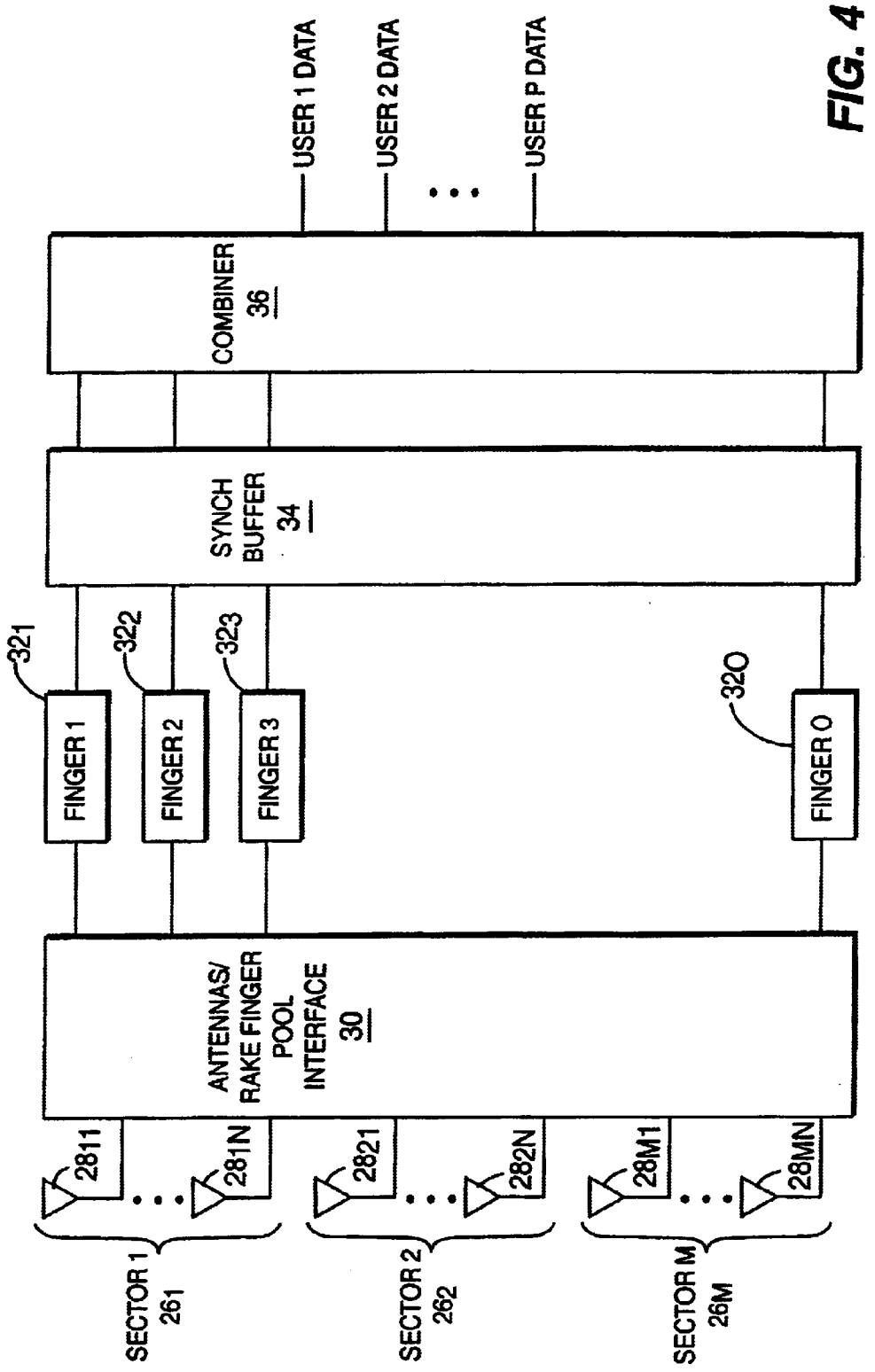


FIG. 2C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USER 2 DATA
USER P DATA
COMBINER 36
SYNCH BUFFER 34
321
322
323
320
FINGER 1
FINGER 2
FINGER 3
FINGER 0
ANTENNAS/ RAKE FINGER POOL INTERFACE 30
2811
281N
2821
282N
28M1
28MN
SECTOR 1 261
SECTOR 2 262
SECTOR M 26M

FIG. 4

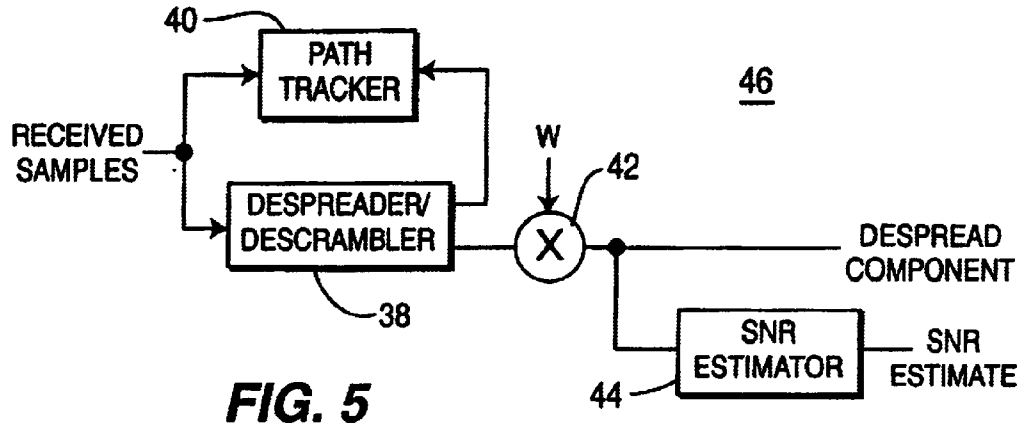


FIG. 5

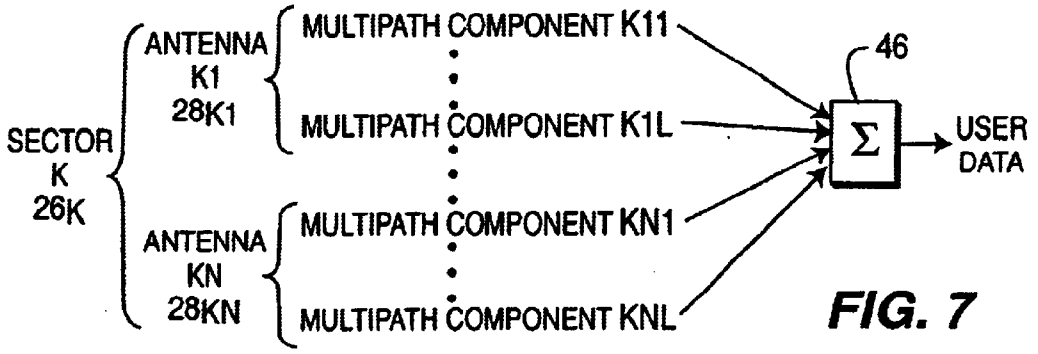


FIG. 7

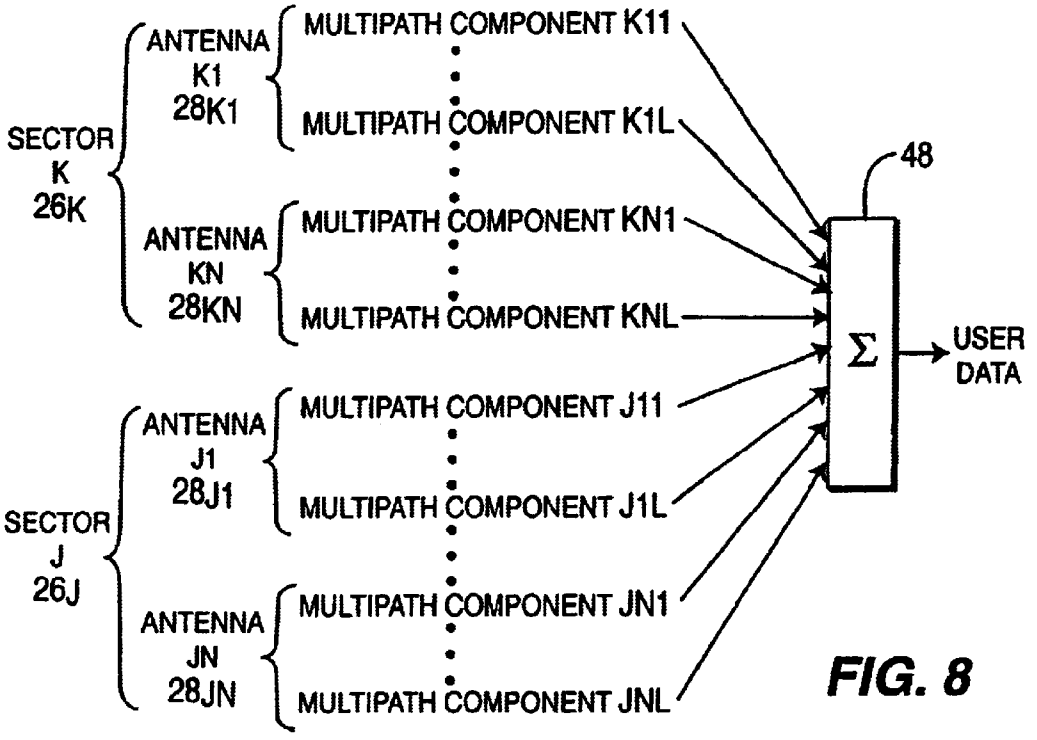
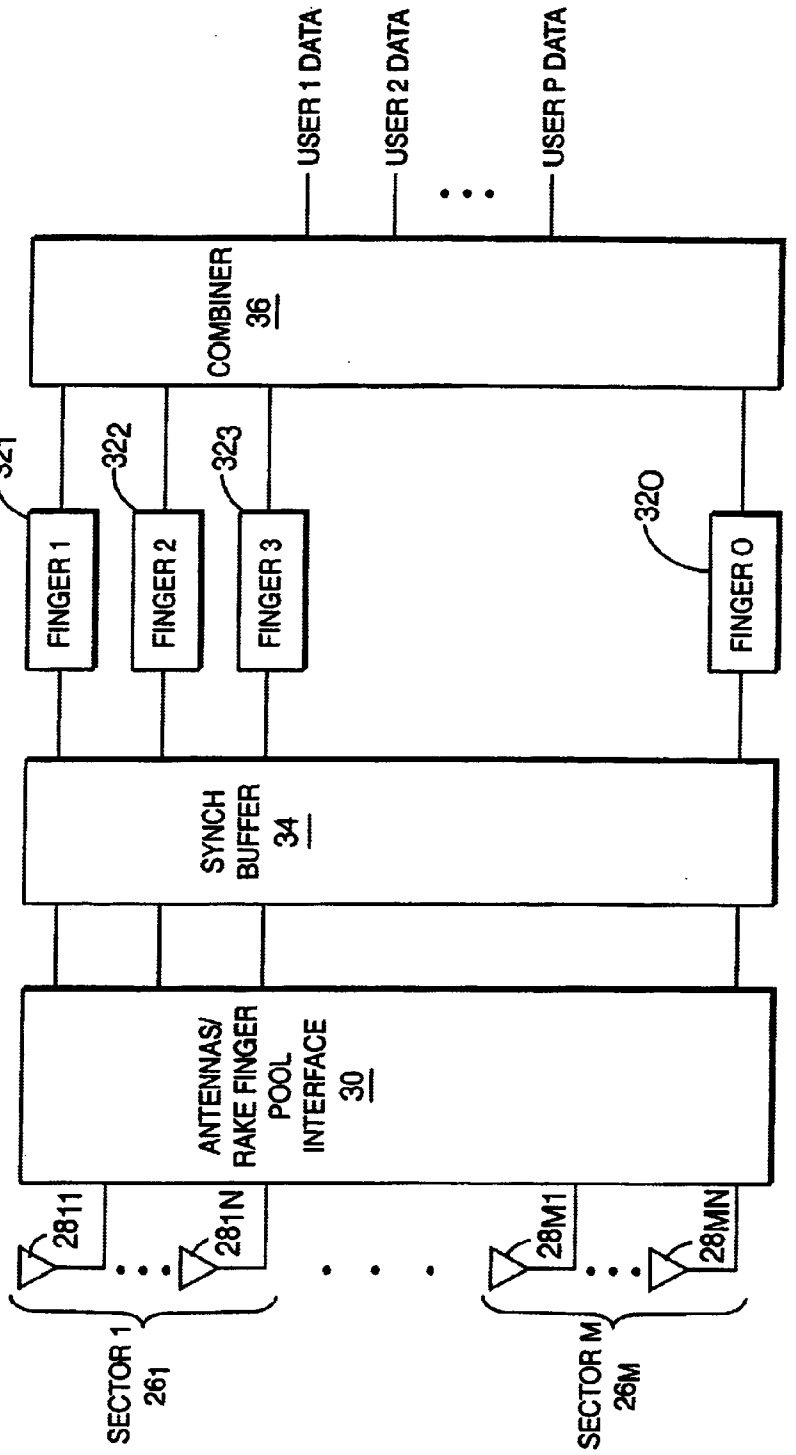


FIG. 8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USER 2 DATA
USER P DATA
COMBINER 36
321
322
323
32O
FINGER 1
FINGER 2
FINGER 3
FINGER O
SYNCH BUFFER 34
ANTENNAS/ RAKE FINGER POOL INTERFACE 30
2811
281N
28M1
28MN
SECTOR 1 261
SECTOR M 26M

FIG. 6

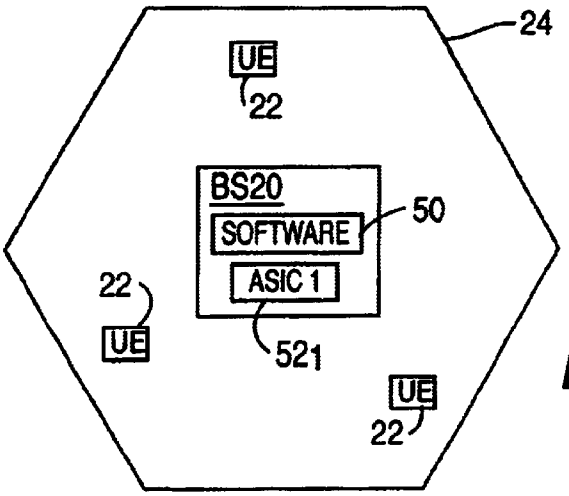


FIG. 9A

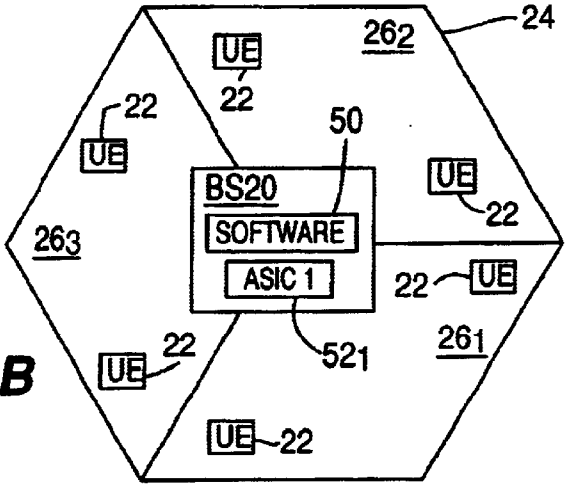


FIG. 9B

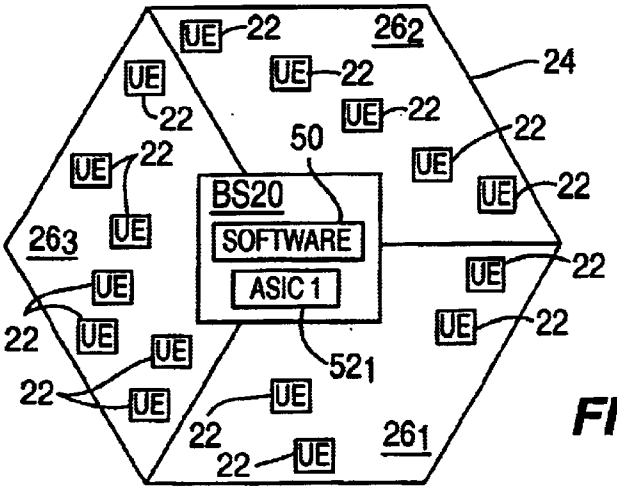


FIG. 9C

NODE-B/BASE STATION RAKE FINGER POOLING

CROSS REFERENCE TO RELATED APPLICATION(S)

This application claims priority from U.S. Provisional Application No. 60/372,531, filed on Apr. 12, 2002, which is incorporated by reference as if fully set forth.

FIELD OF INVENTION

The invention generally relates to wireless code division multiple access communication systems. In particular, the invention relates to receiving user signals in such systems.

BACKGROUND

FIG. **1** is an illustration of a simplified wireless code division multiple access communication system. Each base station $\mathbf{20}_1$–$\mathbf{20}_4$ **(20)** communicates with user equipments (UEs) $\mathbf{22}_1$–$\mathbf{22}_{21}$ **(22)** in its cell $\mathbf{24}_1$–$\mathbf{24}_2$. To illustrate as shown in FIG. **1**, base station $\mathbf{20}_1$ communicates with UEs $\mathbf{22}_1$–$\mathbf{22}_9$ in its cell **24**.

Each cell **24** may also be divided into sectors $\mathbf{26}_1$–$\mathbf{26}_6$ **(26)**, such as six sectors **26** as shown in FIG. **1**. Typically, the base station **20** communicates with each sector **26** using one or multiple antennas assigned to that sector **26**. Each UE **22** in a sector **26** communicates with that sector's antennas.

The distribution of UEs **22** in a cell **24** and sector **26** as well as cell and sector loading may vary. FIGS. **2***a*, **2***b* and **2***c* illustrate varieties in a cell and sector loading. FIG. **2***a* illustrates a lightly loaded three sector cell with even distribution. The UEs **22** in each sector **26** are relatively even. FIG. **2***b* illustrates a lightly loaded cell **24** with uneven UE distribution. One sector $\mathbf{26}_3$ has no users (no UEs) and one sector $\mathbf{26}_2$ has many users. FIG. **2**C is a heavily loaded cell **24** with uneven distribution. One sector $\mathbf{26}_3$ has a few users and other sectors $\mathbf{26}_1$ and $\mathbf{26}_2$ have a large number of users. The base station/Node-B receiver preferably needs to accommodate all of these various loadings.

Furthermore, a UE **22** may move between sectors **26**, such as from sector $\mathbf{26}_2$ to sector $\mathbf{26}_1$, as shown in FIG. **3**. One approach to transfer the handing of the UE **22** between the two sectors $\mathbf{26}_1$ and $\mathbf{26}_2$ is softer handover. In softer handover, during the transition period, the UE **22** communicates with the antennas' of both sectors $\mathbf{26}_1$ and $\mathbf{26}_2$ simultaneously. To improve signal quality during softer handover, it is desirable for the Node-B/base station receiver to accommodate the combining of the communications received by each sector **26**.

Accordingly, it is desirable to have a Node-B/base station receiver capable of handling these varying conditions.

SUMMARY

A Node-B/base station receiver comprises at least one antenna for receiving signals. Each finger of a pool of reconfigurable Rake fingers recovers a multipath component of a user and is assigned a code of the user, a code phase of the multipath component and an antenna of the at least one antenna. An antenna/Rake finger pool interface provides each finger of the Rake pool an output of the antenna assigned to that Rake finger. A combiner combines the recovered multipath components for a user to produce data of the user.

BRIEF DESCRIPTION OF THE DRAWING(S)

FIG. **1** is an illustration of a simplified wireless code division multiple access communication system.

FIGS. **2**A, **2**B and **2**C are illustrations of various sector/cell loadings.

FIG. **3** is an illustration of softer handover.

FIG. **4** is a simplified block diagram of a preferred Node-B/base station receiver.

FIG. **5** is an illustration of a preferred Rake finger.

FIG. **6** is a simplified block diagram of an alternate preferred Node-B/base station receiver.

FIG. **7** is an illustration of combining multipath components of a user.

FIG. **8** is an illustration of combining multipath components of a user experiencing softer handover.

FIGS. **9**A, **9**B and **9**C are illustrations of the scalability and flexibility of the Node-B/base station receiver.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

FIG. **4** is a simplified block diagram of a preferred base station/Node-B receiver for a cell **24**. The cell **24** is divided into M sectors $\mathbf{26}_1$ to $\mathbf{26}_m$ **(26)**. Although M can be any value, preferred values for M are six (6), three (3) and one (1). Each sector **26** has N antennas $\mathbf{28}_{11}$ to $\mathbf{28}_{1N}$ to $\mathbf{28}_{M1}$ to $\mathbf{28}_{MN}$ **(28)** for receiving user communications in that sector **26**. Although N can be any number and can vary in number from sector to sector, preferred values for N are one (1), two (2), and four (4).

The antennas **28** for all sectors **26** are connected to an antennas/Rake finger pool interface **30**. The interface **30** connects the antenna outputs to the Rake finger processors (finger) $\mathbf{32}_1$ to $\mathbf{32}_O$ **(32)** of the Rake finger pool. Each Rake finger **32** is assigned a particular user's received multipath component to recover. To recover that component, each Rake finger **32** is assigned an antenna **28**, code and code phase associated with the received component. An antenna **28** in a sector **26** that the UE **22** resides is connected to the Rake fingers **32** via the antennas/Rake finger pool interface **30**. The code used by the UE **22** is provided to the Rake finger **32** as well as the code phase of the desired multipath components. The Rake finger **32** recovers the multipath component and weights the component prior to being combined with other multipath components of the user.

FIG. **5** is an illustration of a preferred Rake finger **46**, although other Rake finger implementations may be used. The finger **46** receives samples of a received signal from its antenna **28**. A path tracker **40** aligns the finger **46** with its code phase. A despreader/descrambler **38** despreads and descrambles the received samples with the corresponding user code to recover the contribution of that multipath component to the user data. The path tracker **40** also tracks the path and corrects sampling errors via interpolation, for example, so that the de-spreader/descrambler **38** input always appears properly sampled. The contribution is weighted by a complex weighting device **42** to optimize the combining of multiple components. Preferably, the weighting is performed by a maximal ratio combining (MRC), although other weighting algorithms may be used. A signal to noise ratio (SNR) estimator **44** estimates the SNR of the multipath component for use in the weighting and combining algorithms. A compution mechanism for computing the weighting factor (w) is preferably local to the the rake finger **46**. In this embodiment, a path weight generator **43** is provided. The path weight generator typically operates on based on the data component of the despread signal. It is important to note, however, that decision feedback may be used to make the rake finger **46** operate based on the data component of the despread signal.

Referring again to FIG. **4**, each finger **32** preferably operates in isolation from the other fingers and can have the assigned antenna **28**, code and code phase reconfigured to any other antenna **28**, code and code phase. The isolation and reconfigurability allows for versatile utilization of the Rake finger pool for varying environments. Also, the isolation and reconfigurability facilitates implementing the fingers **32** using a small scalable design, which is highly advantageous for use on an application specific integrated circuit (ASIC). For ASICs having a clock rate exceeding the chip rate, each reconfigurable Rake finger **32** can be used to process multiple components. To illustrate, for a 16 times chip rate clock, 16 multipath components can be processed by the same reconfigurable Rake finger during a chip period.

Since the output of the Rake fingers **32** have varying code phase delays, a synchronization buffer **34** is used to synchronize the Rake finger outputs prior to combining. Preferably, the synchronization buffering is performed using a common memory. In an alternate embodiment, as shown in FIG. **6**, the buffering may be performed prior to input of the samples into the Rake finger pool so that the outputs of each Rake finger **32** are synchronized prior to combining.

After synchronization of each Rake finger output, each UE's multipath components are combined by the combiner **36** to produce soft symbols for that user (User **1** Data to User **2** Data). FIG. **7** illustrates combining for a user residing in sector K $\mathbf{26}_K$. For each of the N antennas $\mathbf{28}_{K1}$ to $\mathbf{28}_{KN}$ in sector K $\mathbf{26}_K$, L multipath components (multipath components K**11** to K1L to KN**1** to KNL) are combined, although the number of multipath components combined for each antenna **28** may vary. The N×L components are combined by a combiner, such as a summer **46**, to produce the user data.

FIG. **8** illustrates combining for a user being handed off, by softer handover, between sector J $\mathbf{26}_J$ and sector K $\mathbf{26}_K$. In softer handover, the user is transitioning between two sectors **26**. During the transition, the user communicates with both sectors **26**. For each of the N antennas $\mathbf{28}_{K1}$ to $\mathbf{28}_{KN}$ and $\mathbf{28}_{J1}$ to $\mathbf{28}_{JN}$ in sector J and K, L multipath components are combined by the combiner **48** producing the user data.

The configuration of the Node-B/base station receiver allows for dynamic cell loading and user distributions. The reconfigurability of the Rake fingers **32** allows for allocation of the fingers **32** where needed. For a cell having users evenly distributed among its sectors, the Rake fingers **32** can be allocated evenly to each sector **26**. For cells having sectors with higher loads than other sectors, more fingers can be allocated to the highly loaded sectors. More Rake fingers **32** can also be allocated on demand to users requiring a higher quality of service (QOS) than other users.

FIGS. **9**A, **9**B and **9**C further illustrate the scalability and flexibility of the Node-B/base station receiver. As illustrated in FIG. **9**A, initially an unsectored cell **24** with a light loading is entirely handled by a single ASIC $\mathbf{52}_1$. As the cell loading increases as in FIG. **9**B, the cell **24** is broker into three sectors $\mathbf{26}_1$, $\mathbf{26}_2$, $\mathbf{26}_3$. The flexible reconfigurability of the Rake fingers **32** allows for the same ASIC $\mathbf{52}_1$ to be utilized for the sectored cell. The Rake fingers **32** are allocated to users in the different sectors by modification, such as by software **50**, of the antennas/Rake pool interface **30**. As the cell loading increases as shown in FIG. **9**C, additional ASICs $\mathbf{52}_2$ can be added to increase the overall number of available Rake fingers **32**. The addition of ASICs $\mathbf{52}_2$ allows for scalability of the Node-B/base station receiver.

Preferably, for a receiver having multiple ASICs **52**, each user is assigned to a specific ASIC **52** for processing to facility combining across sectors for softer handover. Since, preferably, none of the Rake fingers **32** are assigned to a sector **26**, combining of a user's received components from multiple sectors **26** is readily achieved. This ability to combine multiple sector components facilitates softer handover as shown in FIG. **8**. Alternately, an ASIC **52** could be assigned to each sector **26**. However, if softer handover is used for an ASIC **52** assigned solely to a sector **26**, an interface for combining the components of the UEs experiencing softer handover is utilized.

What is claimed is:

1. A scalable Node-B/base station comprising:

at least one antenna for receiving signals from users;

at least one application specific integrated circuit (ASIC) having a pool of reconfigurable Rake fingers, each finger for recovering a multipath component of a user, the Rake finger assigned a code of the user, a code phase of the multipath component and an antenna of the at least one antenna;

an antenna/Rake finger pool interface for effectively coupling each finger of the Rake pool an output of the antenna assigned to that Rake finger;

software for reconfiguring the effective coupling as additional ASICs are added at the Node-B/base station, each additional ASIC having a pool of Rake fingers;

a combiner for combining the recovered multipath components for a user to produce data of the user;

wherein the scalable Node-B/base station servicing a plurality of sectors and each user within a cell of the scalable Node-B/base station being assigned to a single ASIC of the ASICs; and

wherein a user transitioning between two of the plurality of sectors and the combiner of the user's assigned ASIC combining multipath components of the user from the plurality of sectors and the Rake finger of only the user's assigned ASIC processing that user's multipath components.

2. The scalable Node-B/base station of claim **1** wherein the Node-B/base station handling a plurality of sectors and the Rake fingers of each ASIC capable of being assigned multipath components from any of the sectors.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,785,322 B1
DATED : August 31, 2004
INVENTOR(S) : Kaewell, Jr. et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

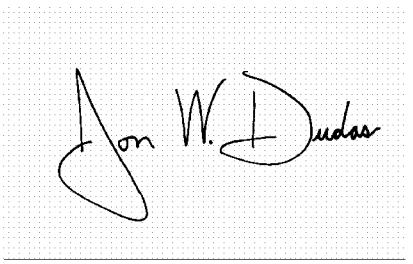
Column 2,
Line 52, after the word "the", delete "de-spreader" and insert therefor -- despreader --.
Line 63, after the word "operates" delete "on".

Column 3,
Line 56, after the word "is", delete "broker" and insert therefor -- broken --.

Column 4,
Line 34, after the phrase "the Rake pool", insert -- to --.

Signed and Sealed this

Ninth Day of August, 2005



JON W. DUDAS
Director of the United States Patent and Trademark Office